PHOTOGRAPHIC QUALITY
vs
FORCED FILM SPEEDS

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EASTMAN KODAK COMPANY, ROCHESTER 4, N. Y.

PHOTOGRAPHIC QUALITY VS FORCED FILM SPEEDS

Not too long ago exposure information on published photographs was quoted simply as shutter time, lens aperture, and film type. This was fully descriptive. More recently, however, there has been a new qualification added to such specifications. In addition to the type of film, now is added the exposure index assigned by the photographer who made the picture. This would lead to a question as to why there appears to be an element of choice in the exposure index, or film speed, which a photographer chooses to assign to the film in his camera. Is the exposure index not a physical property of any given film? Is this figure not determined by the manufacturer according to objective standardized methods? Why then do individual photographers find it necessary or desirable to depart from the published film ratings?

Obviously, each photographer should be striving for optimum quality under the particular circumstances which prevail at each of his picture taking opportunities. Why then isn't the exposure index published by the film manufacturer the last word on this matter? (After all, who has more interest in the excellence of the photographic results than the manufacturer of the film?)

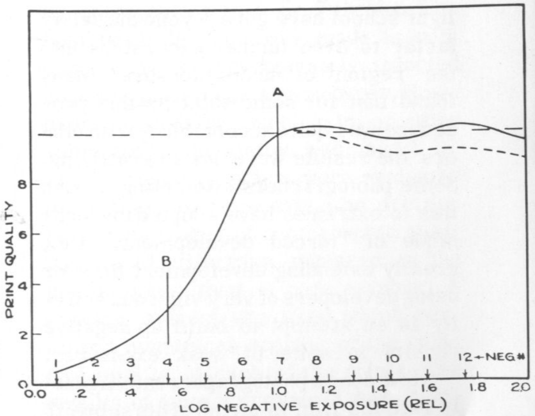
It is well known that exposure indexes for black-and-white negative films are determined by an American Standard method which all of the major film manufacturers follow. It is also well known that this method of sensitivity determination contains a pad, or safety factor, of about 2.5 (about 1 1/3 stops) against underexposure. This protects the photographer against inadvertent underexposure as a result of inaccuracies in his exposure determination and in the calibration of his equipment.

It should be understood that there is, by definition, only one value of American Standard Index for a given film. This is the Exposure Index determined by the American Standard Method. If the American Standard Exposure Index value is set into an exposure meter for the calculation of camera exposure, the resultant exposure settings will, on the average, be about 1 1/3 stops greater than those required to give optimum quality negatives. If we choose to expose a film at some other camera setting, it is necessary to assume a different exposure index value for the film. This assumed value, which is not necessarily directly related to the ASA Exposure Index, may be called (for the purposes of this discussion) the Meter Setting Index (MSI). The MSI value used for any particular film will depend upon the type of result desired, the particular equipment used, the subject and its lighting, etc. Therefore, widely different values for the same film may be used by different photographers. When we choose to expose a film by some such assumed value of meter setting index, we cannot call this setting "American Standard Exposure Index" because this latter is a unique characteristic of a film and cannot be changed by the exposure given the film. Due to film latitude, there is, from the quality standpoint, no uniquely correct exposure and consequently there is no absolute meter setting index. The background work which led to the establishment of the American Standard Method for Determining Exposure Indexes showed that when negatives were made on a given film over a wide range of exposures, the resulting prints were of excellent quality for a considerable range of the negative exposures. Of course the quality was very low for grossly underexposed negatives. As exposure was increased, quality improved until it reached an optimum, beyond which it showed no significant change until very great overexposure was reached. For the reasons given previously, the safety factor in exposure index was chosen so as to place the exposures well up into the optimum exposure range, so that there would be some exposure latitude on each side of the aim point.

The investigations of Jones and Nelson ("Effective Camera Speeds of Photographic Negative Materials," L.A. Jones and C. N. Nelson, from Journal of Photographic Society of America, Vol. II, No. 1, February 1941) showed that as exposure was increased from a very low value, quality rose until it reached a plateau. In a wide region of greater exposures there was little change in print quality -- based on judgment of contact prints. Hence, the exposure needed only be placed somewhere to the right of the curves shoulder to be in the region of optimum quality. How far the exposure was to the right of the shoulder was not really important. Thus, most photographers in those days tended to expose a bit heavily "just to be sure" they didn't lose quality by accidental underexposure. In the days when contact printing was more common, a bit of overexposure did no real harm.

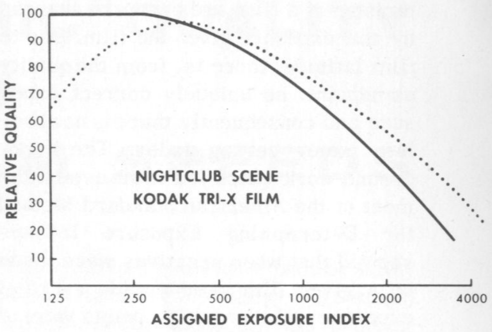
With the new emulsions which have been introduced in the last few years, photographers have discovered that the exposure latitude is somewhat narrower than the four or five stops of the older films. They have also found that with modern cameras, whose shutters and coated lenses are of high efficiency, and with modern photoelectric exposure meters which make light measurements somewhat more precise, the safety factor could be dropped wholly or in part with attendant advantages of higher shutter speeds and/or greater depth of field.

This narrowing of the optimum quality plateau of the quality curve can be attributed in part to advances and changes in photographic practices. By far, the large majority of photographs are currently made by enlargement rather than by contact printing. When judging contact prints, one can go a great distance into the region of overexposure



Graph showing relationship between negative exposure and quality of the best prints obtainable from the negatives. (Jones and Nelson, 1941.)

Exposed at rated Exposure Index.
See caption page 7.



before loss in quality becomes apparent since most films will maintain some degree of linearity of tonal separations even at exposures several hundred times optimum. But, upon enlargement, the loss in image quality due to increasing graininess, image spreading, etc., becomes very apparent after only a short departure from optimum exposure in the overexposure direction.

Having discovered that they could "up the index" by an appreciable amount, some photographers of the available light school have gone beyond the safety factor to even further excursions into the region of underexposure. Many found that for some subjects this procedure was quite acceptable — with others the results were not so gratifying. Some photographers attempting to push this to extremes have adopted the technique of "forced development," i.e., greatly extending development time, or using developers of very vigorous activity in an attempt to build up negative density in spite of weak exposures.

How does a photographer intelligently rate his film in terms of his subject? How far can he go in the direction of underexposure before quality begins to suffer noticeably? What can be accomplished with forced development? How does forced development affect photographic quality?

The Kodak Research Laboratories set up an experimental project in an attempt to obtain some significant quantitative answers.

The method of approach was as follows: After considerable discussion, six scenes were chosen which represented the extremes in brightness scale and in illumination level which the average photographer encounters. Three of the scenes were of generally high level intensity in lighting, and the other three were of generally low intensity. In each intensity series there was a high, medium, and low brightness scale subject. (See photos.)

Each scene was given several identical exposure series. Each series ranged from the American Standard Exposure Index to 32 times this value, in steps which doubled the effective exposure index for each succeeding exposure in a series. Thus, a single series on one subject consisted of exposures at the normal index, 2 times the index, 4, 8, 16, and 32 times. This resulted in exposure settings corresponding to meter setting indexes of the order of

D76

Exposed at 2X the rated Exposure Index

Exposed at 4X the rated Exposure Index

6,000 to 8,000 for the fast film, and of the order of 1,000 for the slow film.

All exposures were made with the same 35mm camera which had a calibrated shutter and diaphragm. The shutter was carefully tested and found to have good reproducibility.

With each scene, three identical exposure series were made on Kodak Tri-X Film, and, in addition, with three of the scenes the same thing was done on Kodak Panatomic-X Film. Panatomic-X was not used on the low level medium brightness scene or on the two high brightness scale scenes because it would not be a general choice for these types of photographs.

The first of the three identical exposure sequences of each scene was processed as recommended in D-76. In the case of the Tri-X Film this was 11 minutes. For the Panatomic-X Film, the normal development was 7 minutes in D-76 diluted 1:1. In all cases, D-76 was used undiluted for the Tri-X Film.

The second exposure series was given "extended development" consisting of a 100% increase in the time of immersion in the developer, i.e., 22 minutes for the Tri-X, and 14 minutes for Panatomic-X.

The third series of exposures from each scene was "forced" in development by giving it three times the normal developing time — 33 minutes for Tri-X, and 21 minutes for Panatomic-X. This was felt to be the practical limit for forcing since the development fog level was becoming prohibitively high in the negative subjected to this amount of forcing. Standard temperature and agitation were followed rigidly throughout the processing. From the processed negatives, prints were made by enlargement to 5 by 7 inches. The best possible print was made in each case using the appropriately selected contrast grade of enlarging paper. However, no dodging, burning-in, or other subjective manipulation was used.

The resulting prints were evaluated by a panel of personnel who are experienced judges of photographic quality. No identification appeared on the prints other than a code number. A grading system was used which permitted numerical scoring of the relative quality of each of the prints. The results of quite a number of these judgings were averaged for each print, and this quality score for each print was used to make the graphical presenta-

Exposed at 8X the rated Exposure Index

Exposed at 16X the rated Exposure Index

HOW TO READ QUALITY CURVES

At the intersection point of the normal (solid line) and extended (dotted line) development curves, the exposure level is such that extended development and recommended development give equal quality (with appropriate adjustment in printing). The extended-developed negative may be slightly easier to print and may go on a lower grade of paper, but its quality will be comparable to the normally developed negative, properly printed. To the left of this point, in the region of less underexposure, the normally developed negatives always yielded better quality prints than those given forced development. To the right of this point, further into the region of underexposure, the extended-developed negatives yielded prints of somewhat better quality than those given normal development. A vertical dropped from the point of intersection to the base indicates the assigned exposure index at which this point of "equal quality" occurs for the particular situation and film for which the curves were plotted.

tions by plotting against the meter setting index at which the negative for each print had been exposed. The resulting curves then represent photographic quality as a function of negative exposure.

Before going on to the test results, it may be well to discuss some of the attributes and factors of that elusive quantity loosely called "photographic quality." In general, quality consists of two major ingredients; tone reproduction and image definition.

Tone reproduction refers to how faithfully the brightness qualities in the subject are reproduced in the black-and-white print. It depends upon the degree of exposure and development, the scale of the film (the range of brightness values which it can record), the printing paper, the exposure in the enlarger, and finally the amount of non-image forming light (flare) in the whole system — camera and enlarger.

Definition relates to the sharpness, or acutance, of sharp edges in the picture. It is affected by the granular and light-spreading characteristics of the negative material and the optical characteristics of the camera and enlarger lens. To a large extent, graininess is

Long brightness scale and high intensity: Illumination on the singer in the spotlight was 100 foot-candles. The brightness scale of reproducible tones was approximately 160:1, although this figure was difficult to pin down precisely since there were areas which received so little illumination (under the tables) that no minimum reading was possible. The highlight areas, that is the girl and her white dress, were brilliantly illuminated while the people at the tables and the pianist were darkly clothed and only indirectly illuminated by spill light. Basic exposure - Tri-X 1/25 at f/5. Panatomic-X was not used.

also influenced by the density level of the negative, the extent of development, the grade and surface of printing paper, and the degree of enlargement. Sharpness is dependent, too, on the amount of camera and subject movement that occurs while the lens is open, and frequently also on the depth of field of the lens.

In the test scenes used in this work, brightness range (or ratio, or scale) is simply the ratio of the brightness of the most brilliant highlight in the scene as compared to the deepest shadow in which detail is of significance. Brightness includes not only the factor of the illumination falling on the particular element of the scene, but also the reflectance of the surface of that element. The stated brightness range ratios are for scene brightnesses and would be reduced in the image in the camera by a constant factor of about 2.5 due to flare with uncoated multi-element lenses. (Coated lenses reduce this factor somewhat.)

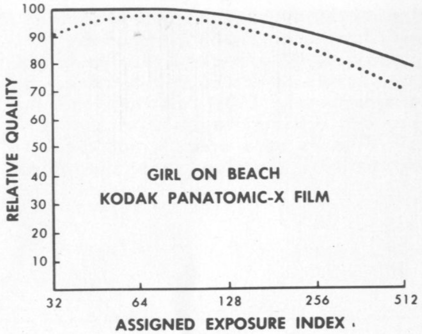
The "average" scene is assumed, for photographic purposes, to have a brightness ratio of about 128:1. Scenes with much greater ratios than this are said to be "contrasty" and those with appreciably shorter ranges are commonly called "flat."

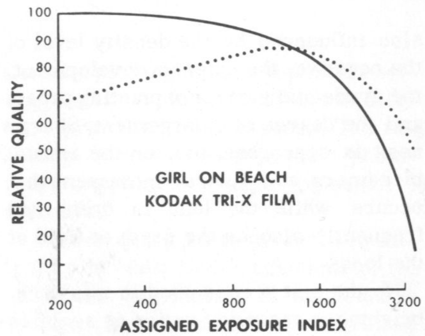
The brightness ratio should not be confused with the lighting level of the scene which is the integrated total light incident on the scene. There can be scenes of high level and low brightness range as in the beach scene in this work, or there can be scenes of low level and high brightness range as in the railway station shot.

CONCLUSIONS

The curves are self-explanatory. The general observation can be made that with Tri-X Film, picture quality for recommended development holds up reasonably well through meter setting indexes in the order of 4 times the American Standard Exposure Index for the short scale scenes. For the medium brightness range scenes, around 2.5 times the rated Exposure Index is about the limit. For the long scale scenes, 2 times is the limit for optimum quality.

With Panatomic-X Film, the short scale scenes showed no loss in quality up to meter setting indexes of 3 times the normal Exposure Index and only slight loss up to 4 times.



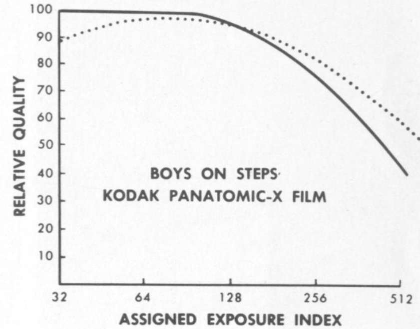


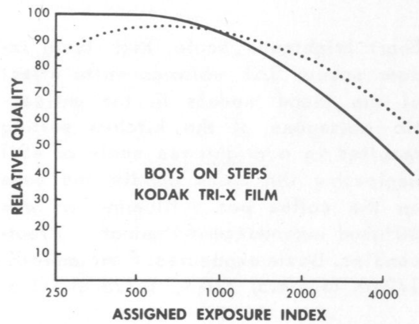
Low brightness range, high level illumination: The brightness ratio was 40:1 (excluding the dark glasses) and the illumination level was 9,000 foot-candles from summer sunlight at about noon. White sand, towel and bathing suit combine with the model's fair skin and hair to produce a scene which is quite flat even though illuminated brilliantly. Basic exposures—using Panatomic-X: 1/125th second at *f*/8; Tri-X film: 1/1000th second at *f*/8.

Extended development curves show that films developed to the recommended degree exhibited superior photographic quality to those given extended development through the range of normal exposure. It was only when the order of underexposure reached about 8 times that the quality of the normally developed pictures dropped to such an extent that extended development provided some improvement. This was probably due to a slight film speed increase, and to somewhat better printing density and gradient in the negatives given extended development. At no level of exposure did the quality of the extended developed pictures become as good as those given normal development and reasonable exposure. It was only when the degree of underexposure had reached the unacceptable stage that the extended developed pictures became slightly better than those given normal development.

The forced development (200% overdevelopment) results were not tabulated since they were universally of such low quality that none of them would be acceptable. These negatives were dense and difficult to print and the resulting prints exhibited very poor image quality. From this it can be inferred that someplace between 100% and 200% lies the limit for forced development to any useful advantage at all.

In five and ten-diameter enlargements from the 35mm negatives, only barely perceptible differences in qual-



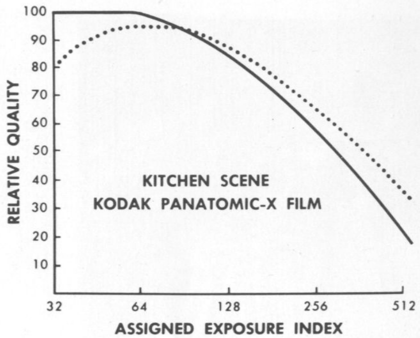


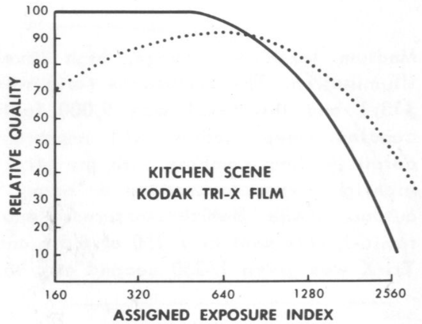
Medium brightness range, high level illumination: The brightness ratio was 113:1 and the level was 9,000 foot-candles. Deep shadows with important detail in them combine with the bright highlight areas to produce a "normal" outdoor scene. Basic exposures—Panatomic-X was shot in 1/250 at *f*/5.6 and Tri-X was given 1/250 second at *f*/16.

ity between exposures made at normal and twice normal exposure index could be detected in most cases. The advantages of shooting at the advanced meter setting index became apparent, however, when giant blowups were made. Tone reproduction characteristics stay about the same as long as the film is exposed within its usual 2.5 x safety factor, but exposures close to the minimum in this range keep image definition at its best and graininess its least in the big enlargements.

These tests and recent trends in photography have occasioned a fresh look at the subject of film ratings. The manufacturer's interpretation of the usefulness of the present system of exposure indexes in the hands of serious photographers in quest of optimum quality has become more liberal than it was.

Another factor affecting this new approach to the exposure index question is the increasing number of pictures taken on small negatives. Not long ago, film manufacturers felt that the 1 1/3 stop safety margin allowed by standard ratings was optimum from the standpoint of utilizing the exposure latitude of the system to protect the average photographer from the hazards of underexposure. Part of this attitude was colored by the fact that slight overexposure does not noticeably affect quality of pictures made on big negatives. The growth of 35mm photography, in particular, has showed up inadequa-





Short brightness scale, high level indoor scene: The white-on-white effect of the blond models in the antiseptic whiteness of the kitchen setting resulted in a brightness scale of 45:1 neglecting the black handle and base on the coffee pot. Illumination was diffused incandescent light of 600 foot-candles. Basic exposures: Panatomic-X, 1/25th at *f*/4.5; Tri-X, 1/125 at *f*/5.6.

cies in present ratings. With small negatives, definition loss from heavy overexposure is a more serious problem than with larger negatives. A definite loss of quality is seen that was not apparent when larger negatives were exposed and contact printed.

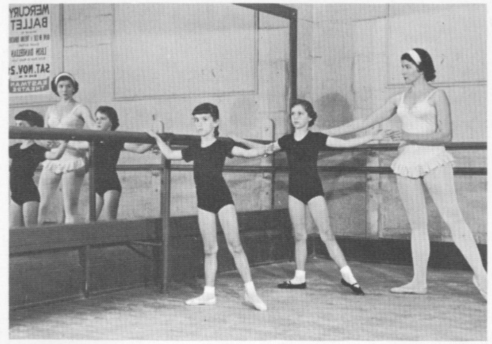
A second influence working against the present film rating system is the psychological safety factor that most people put into their exposures almost subconsciously. The average picture-taker often purposely errs about one stop on the side of overexposure, "just to be sure" he has enough exposure.

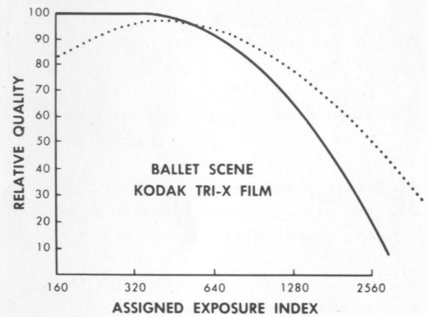
Improper use of exposure meters by many people who take pictures is a third influence that often brings over-exposed results to photographers who think that they are exposing correctly.

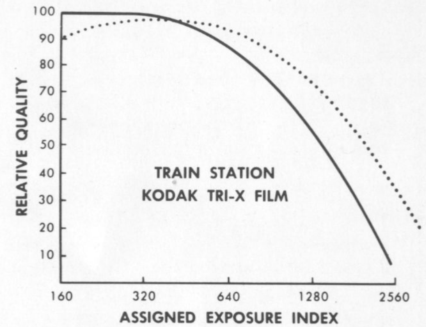
Add to the above two mechanical factors: First, coated lenses which provide lower flare factors than before, and second, many between-the-lens shutters used in the cameras of serious photographers actually have longer open periods than their markings indicate. This is especially true when shutters are used at high speeds with small lens apertures.

Results of these experiments point up two suggestions for the serious photographer:

First, he should determine the proper exposure level for his own equipment and his method of reading light. This can be done simply by running some carefully exposed and processed exposure tests on the types of scenes he generally photographs.







Medium brightness scale subject of low intensity: The brightness scale measured 110:1 and the level was 32 foot-candles. Basic exposure—Tri-X: 1/5th of a second at *f*/6.3. Panatomic-X was not used because it would not be a likely choice of film for a photograph of this type unless sufficient additional illumination was provided.

Long brightness scale, low intensity scene: Total illumination here came from the 100-watt incandescent lamps in the overhead reflectors on the station platform, resulting in a level of less than 3 foot-candles and a brightness range of 163:1. Basic exposure for this shot—Tri-X: Four seconds at *f*/5.6. Panatomic-X was not used.

Second, he should stick to normal development except in those rare instances when an image must be salvaged in spite of very severe underexposure. This means, incidentally, that he should guard against unintentional forcing of his development. Solutions of improper strength or temperature, or overly vigorous agitation can cause forced development and a consequent reduction in photographic quality.

Armed with exposure information for his own particular equipment and guided in the darkroom by the instructions for a familiar and reliable developer like Kodak Developer D-76, it's more than likely that the average photographer can enjoy shooting Panatomic-X outdoors at an MSI of about 64, or Kodak Tri-X indoors at an effective MSI of around 400; and he'll be pretty sure of getting top-quality photographs.

Easily drawn conclusions are that, when normally processed, today's films often can be used best at levels somewhat above the published exposure index, and that in low-brightness ratio scenes they can be pushed to higher meter setting indexes than in situations where the scene brightness scale is longer. Since the quality fall-off with overexposure is swift, it can be generally concluded that the photographer who shoots at a higher-than-rated index -- after first finding the proper level with his particular equipment by some experimentation — will usually obtain the best results.

HOW TO DETERMINE YOUR OWN METER SETTING INDEX

To find your own MSI tailored to your equipment and preferences in negatives and prints, proceed as follows with your favorite film(s):

1 – Select one or more scenes according to an estimate of their brightness ratio. Use the accompanying illustrations as a rough guide.

2 – Measure the exposure carefully with an exposure meter following the instructions which came with the meter.

3 – With the calculator on the exposure meter, determine the camera settings using the American Standard Exposure Index for the film.

4 – Make the exposure, preferably with your camera on a tripod or other steady support. Keep a record of your exposure settings.

5 – Again use the meter calculator but this time use an MSI of twice the Exposure Index.

6 – Change the camera to the new exposure settings and make the second exposure. (In selecting the new exposure, change the shutter speed and leave the diaphragm as nearly constant as possible. When you reach the top shutter speed setting, it will be necessary to close the diaphragm to continue the series; but keep the aperture within one or two stops in order to make the pictures comparable from a depth-of-field standpoint.)

7 – Repeat steps 5 and 6 doubling the MSI of the preceding step until you have reached a reasonable limit.

8 – Remove the film from the camera and develop in your favorite developer by your usual technique.

9 – Make the best possible print from each negative in the series.

10 – Evaluate the prints with regard to photographic quality – the highlight detail, shadow detail, ease of printing in your own equipment, overall print brilliance, etc. Select the one that YOU like best. From your data determine the MSI that you used to make this picture.

11 – In the future use this MSI for scenes of the same general brightness ratio on the same film with the same processing.

12 – Repeat the above exposure series with other films and/or other developers that you use regularly to determine your MSI for these other combinations or conditions.

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